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Model cloud parameter validation using AIRS radiances

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Data Assimilation and Satellite Meteorology Research Section

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Background

- AIRS radiances assimilated operationally at EC (since June 2008)
  - 87 channels
  - radiances not sensitive to lower clouds are assimilated
- Therefore need to validate cloud height/amount determination for improved quality control
- By extension interest in validating trial fields of cloud parameters and more generally cloudy radiance spectra to infer model deficiencies
- Specific problems found in Arctic/Antarctic region linked to cloud parameter determination. Validation with independent data needed (MODIS, Calipso, MISR datasets)

Basic idea

Model output combined with calculated cloudy radiances allows to validate cloud parameter retrieval methodology

- Effective cloud height and amount derived from CO_2- slicing technique using observed AIRS radiances
- Same methodology used with calculated cloudy AIRS radiances from 6-h and 12-h forecasts

⇨ Eliminates ambiguity of definition of cloud parameters related to observed versus calculated.

⇨ Still a need to validate the quality of retrieved parameters

Methodology

INPUT:

Collected data: AIRS 281-channel set reduced to center pixel in 3X3 "golf ball"

Forecast model: EC global model, 600 X 800 grid (~35 km), 6 h forecast (valid interval 3-9h) and 12h forecast (valid interval 9-15h)

Radiative transfer model: modified RTTOV 8.7 version

Cloud optical properties: cloud overlap scheme [*Räisänen, 1998*], fixed liquid particle size (10 µm radius over land and 13 µm radius over ocean), ice particle size parameterization [*McFarquhar et al. 2003*]

Räisänen, P.: Effective longwave cloud fraction and maximum-random overlap of clouds: a problem and a solution, *Mon. Weather Rev.*, **126**, 336-3360, 1998.

McFarquhar, G. M., S. F. Iacobellis, and R. C. J. Somerville: SCM simulations of tropical ice clouds using observationally based parameterizations of microphysics. *J. Climate,* ***16,*** 1643-1664, 2003.

Methodology

OUTPUT:

- All sky radiances/brightness temperatures from model output (one observed and two calculated using both forecasts
- Cloud top pressure(CTP)/height(HT) and cloud fraction(CF) from EC CO_2-slicing method using observed and calculated radiances
- CTP/HT and CF using directly the model output

Additional cloud parameters:

- CTP/HT and CF from AIRS Science team
- CTP/HT and CF from MODIS Science team
- CTP/HT and CF from EC GOES processing

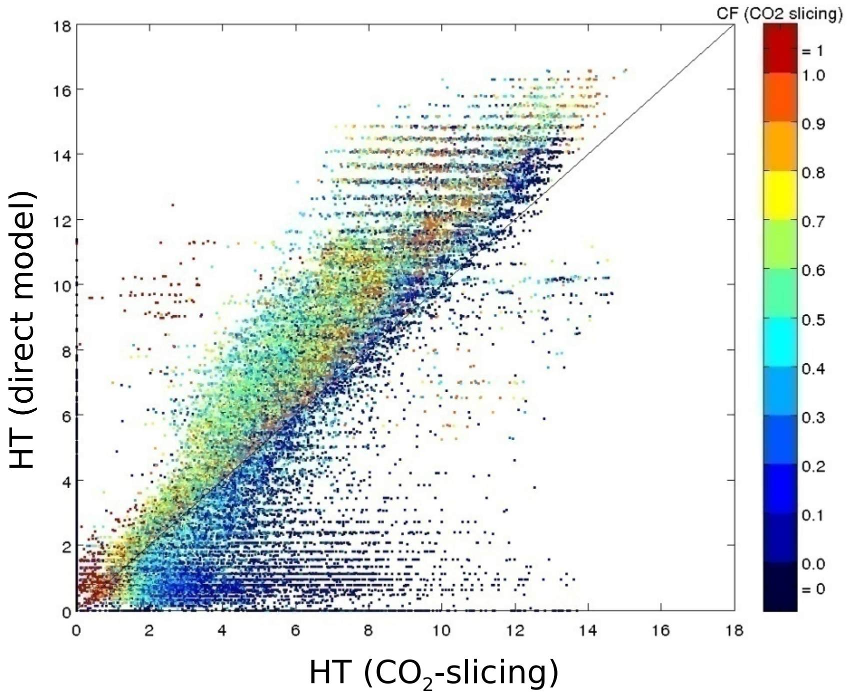
Latitude Longitude grid: 1° x 1° (mapping grid)

Direct output model

Cloud parameters derived from direct model output are sensitive to the threshold value τ_{cloud}

CTP/HT = downward cloud transmittance from model top reaching 1 - τ_{cloud}

Effective cloud amounts < τ_{cloud} ignored



$\boldsymbol{\tau_{cloud}}$ **= 5 %**

τ_{cloud} **= 10 %**

τ_{cloud} **= 20 %**

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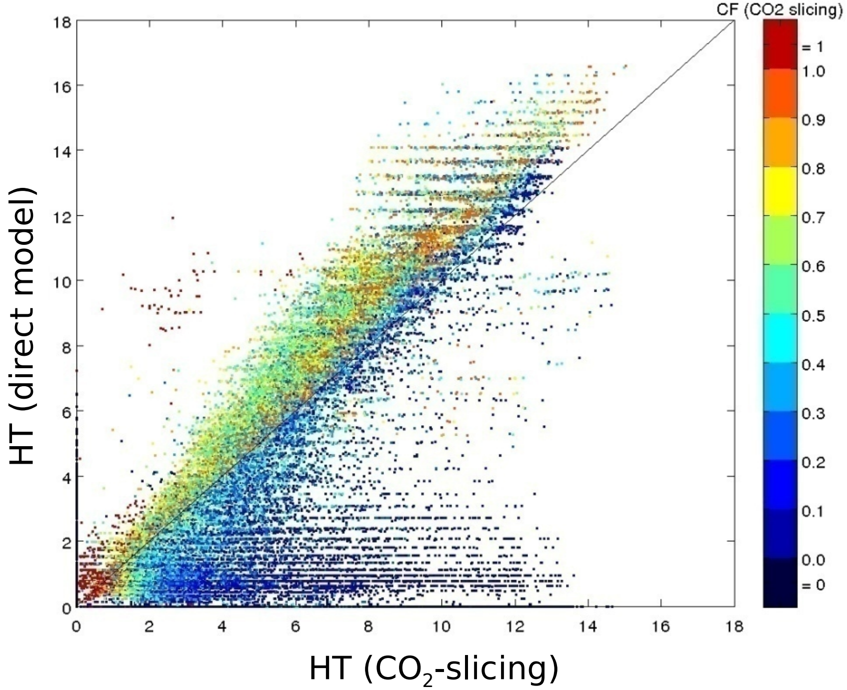

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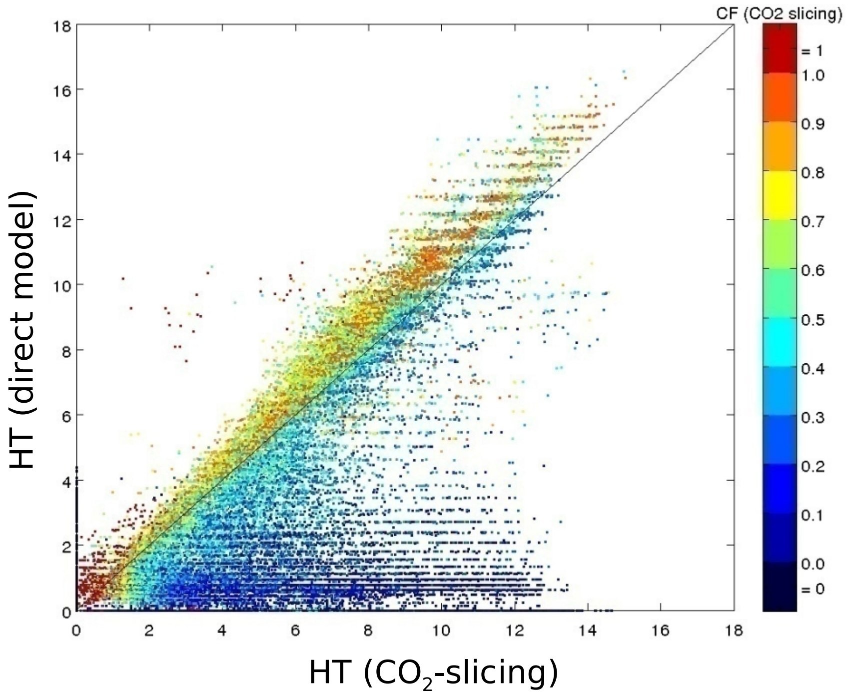


τ_{cloud} = 5 %

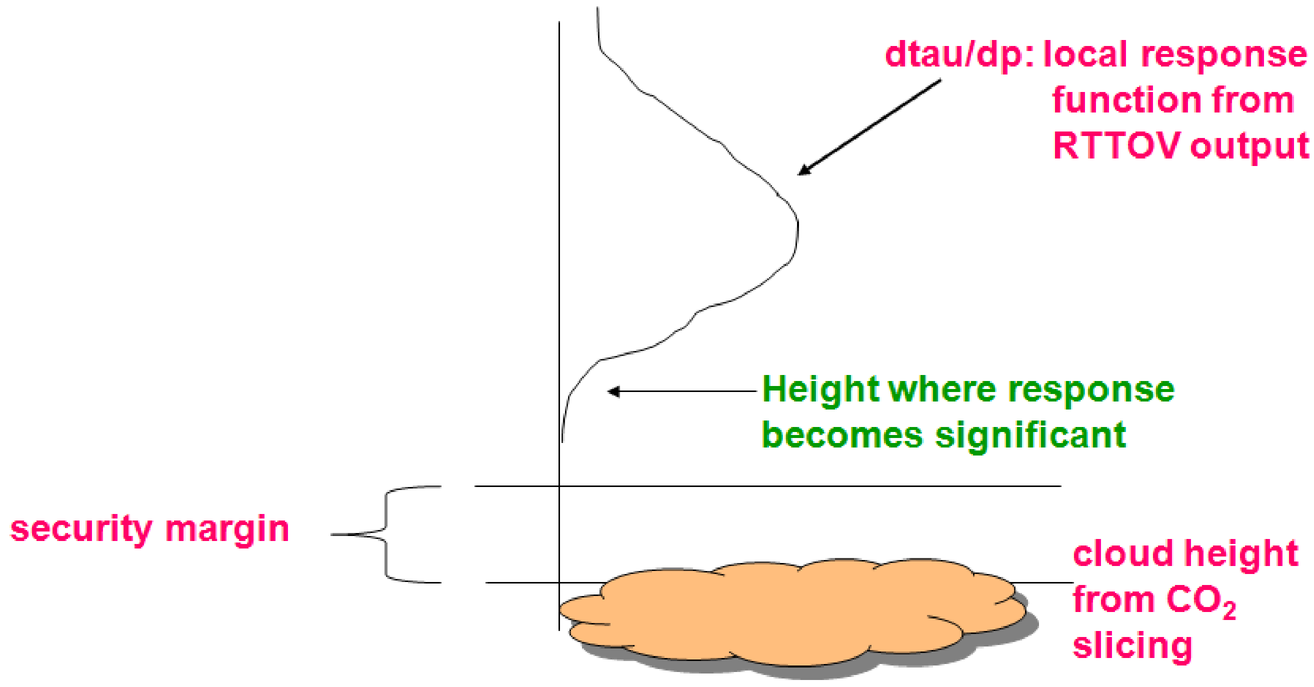
τ_{cloud} = 10 %

τ_{cloud} = 20 %

Increasing the threshold will decrease the bias, but also the detection of multilayer clouds
A compromise value of 10 % was chosen for future tests

CO_2-slicing technique: cloud height/amount

- CO_2 slicing: estimates of cloud height from as many coupled channels. Mean of valid estimates is used.
- Security margin is max (50 hPa STD among valid estimates)

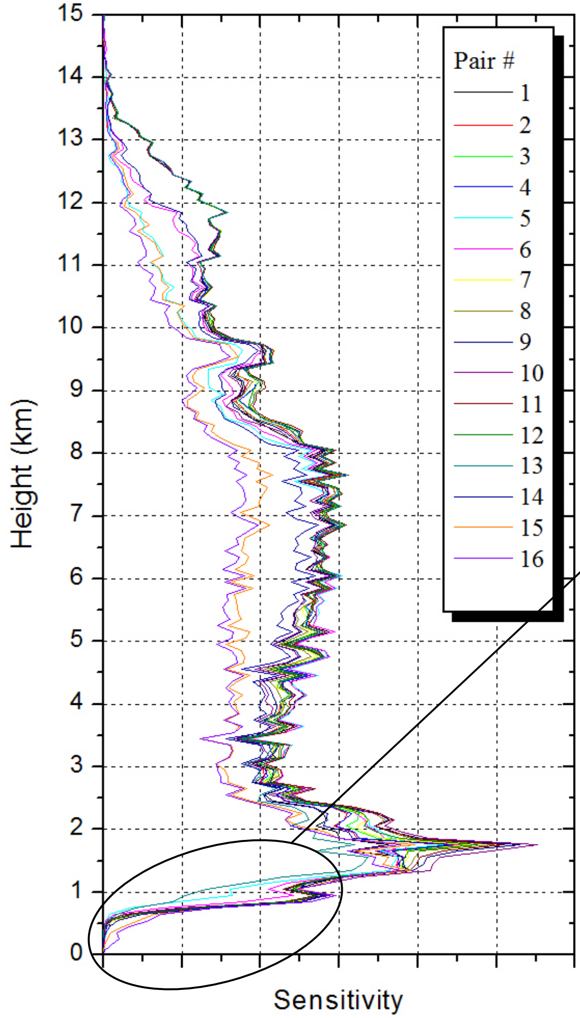


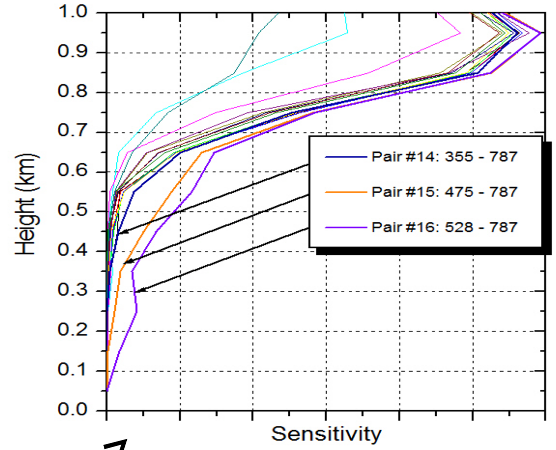
CO_2-slicing technique: channels configuration

Initial configuration: 12 channels coupled with a reference profile peaking near the surface	
Channel #	Wavenumber
204	707.770
221	712.661
232	715.862
252	721.758
262	724.742
272	727.752
299	735.298
305	737.152
310	738.704
355	752.970
362	755.237
475	801.001
Reference channel	
787	917.209

Last configuration: 16 pairs of coupled channels				
	Channel		Reference channel	
Pair #	#	cm-1	#	cm-1
1	**204**	707.770	**252**	721.758
2	**221**	712.661	**262**	724.742
3	**232**	715.862	**272**	727.752
4	**252**	721.758	**299**	735.298
5	**262**	724.742	**305**	737.152
6	**272**	727.752	**310**	738.704
7	**299**	735.298	**355**	752.970
8	**305**	737.152	**362**	755.237
9	**310**	738.704	**375**	759.485
10	**355**	752.970	**375**	759.485
11	**362**	755.237	**262**	724.742
12	**375**	759.485	**252**	721.758
13	**375**	759.485	**204**	707.770
14	**355**	752.970	**787**	917.209
15	**475**	801.001	**787**	917.209
16	**528**	820.731	**787**	917.209

CO_2-slicing technique: channels configuration





Channel pair sensitivity at a certain height H is defined as number of valid estimates (percentage from total data set)

Vertical sampling: 100 m
Data set: July 1st, 2008, 00Z

The sensitivities of the first 13 pairs (not employing the channel #787) have the same shape

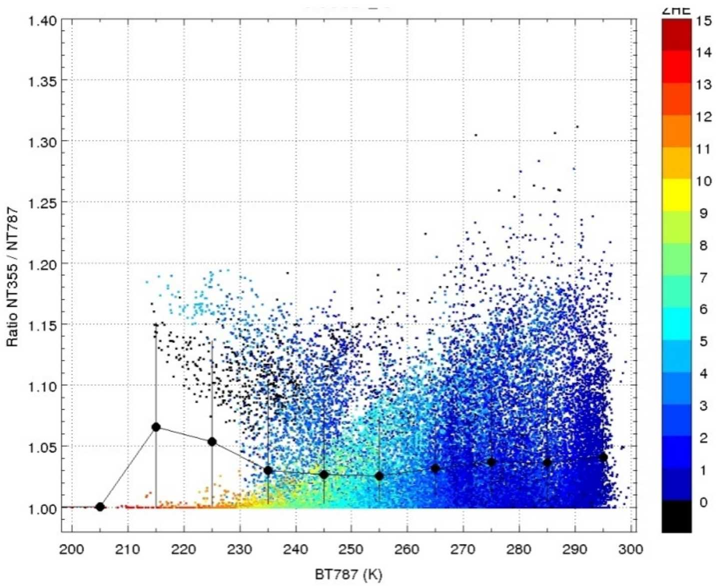
All pairs have difficulties peaking near the surface; only the last 3 pairs (employing the channel #787) present a weak sensitivity in the first 500m

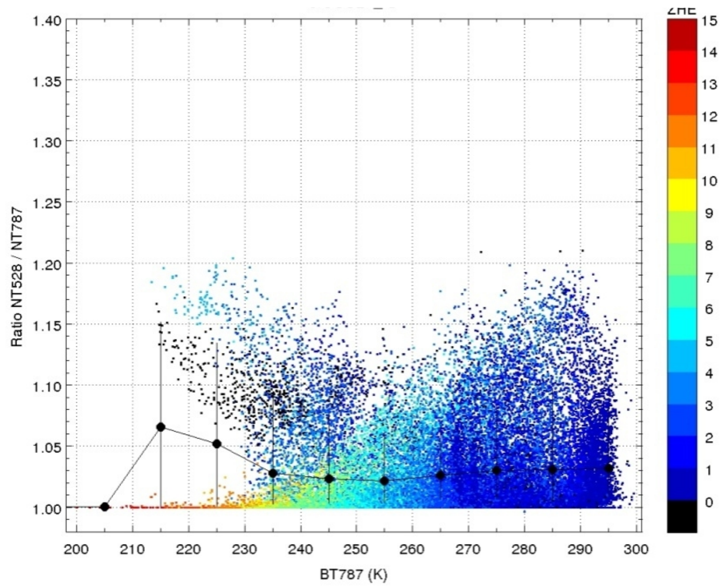
Next step: assuming that the coupled channels have different emissivities (last 3 pairs only)

CO_2-slicing technique: channels configuration

Emissivity ratio vs brightness temperature (channel 787)

355/787 528/787





Emissivity ratio could be given by the detected cloud amounts ratio and varies up to 1.15
Color scale = cloud top height
Black plots = mean ratio and STD for 10 K bins

Preliminary conclusions: the effect obtained using channel 787 combinations is weak compared to the others coupled channels; for the future we might consider only the first 13 pairs of channels

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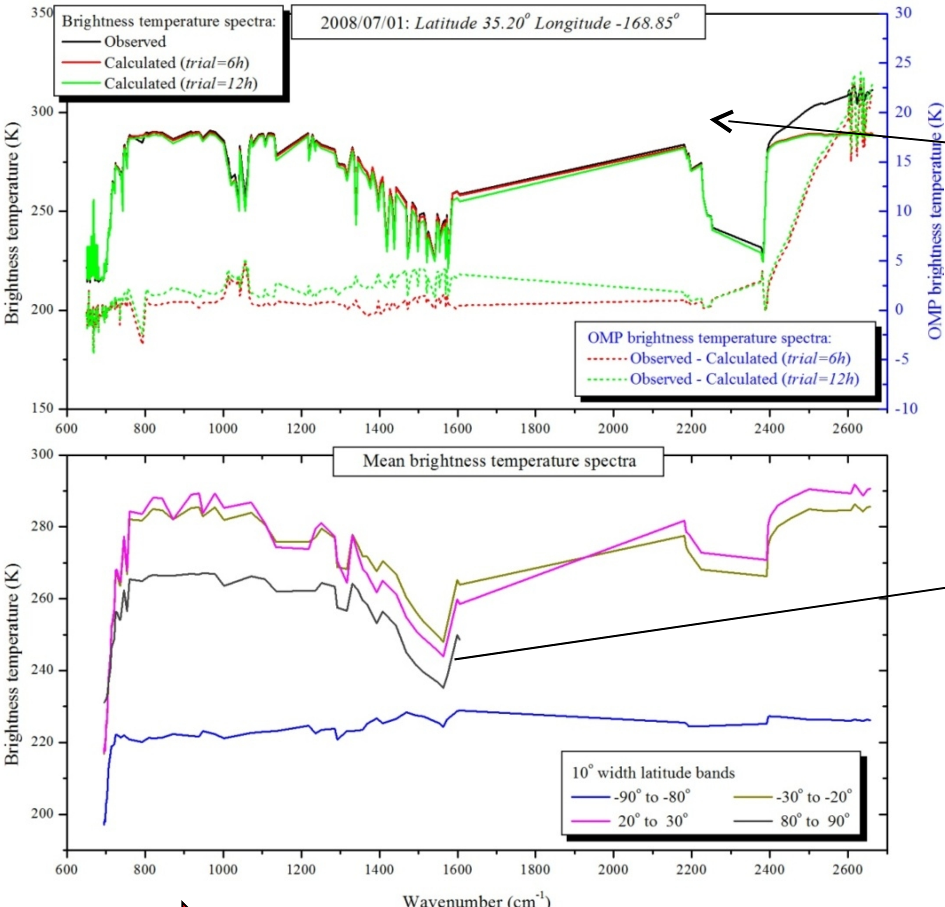
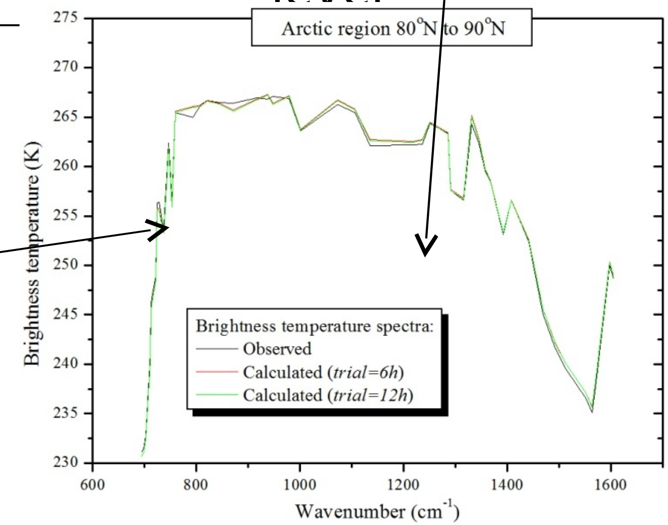
Observation vs Simulations: Brightness temperature comparison

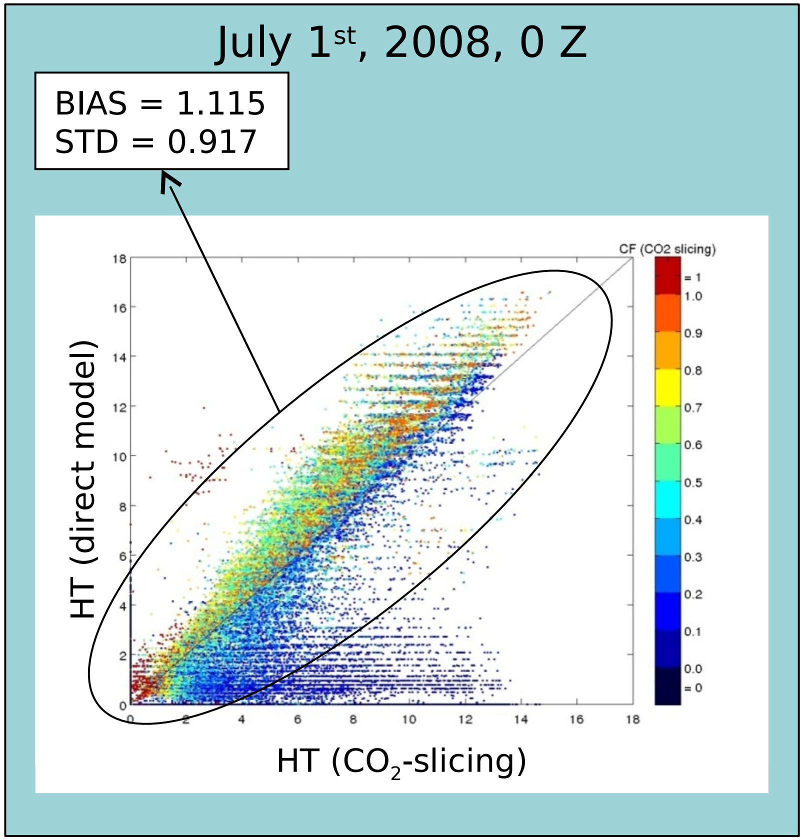


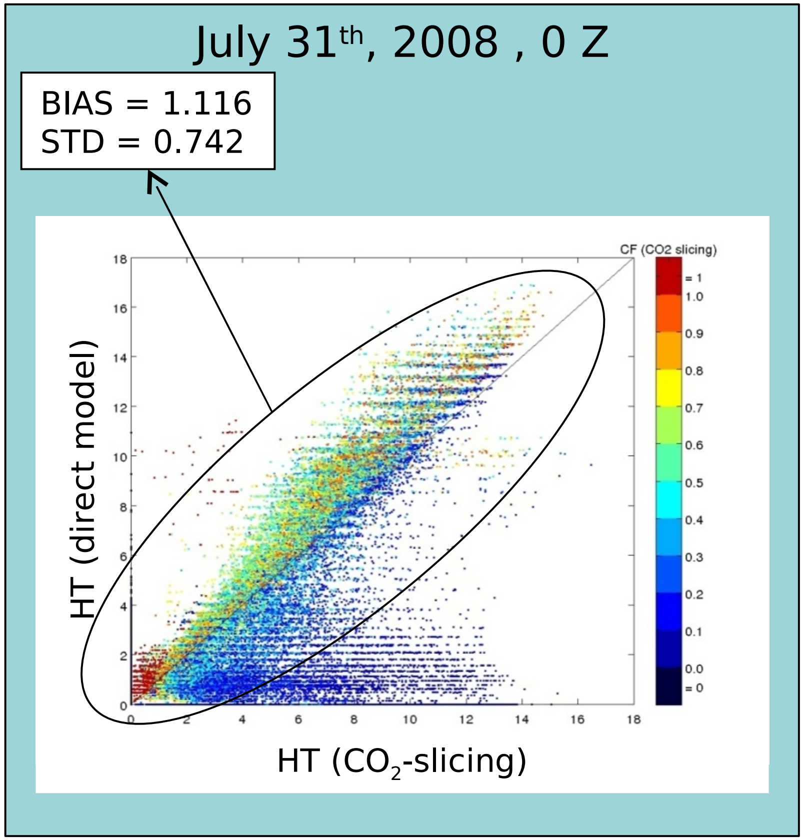
Good agreement between observed and calculated radiances at pixel level as well as at monthly mean level



80-90 S spectrum remarkably flat: difficulty of sounding in polar night conditions

Validation results: cloud top height

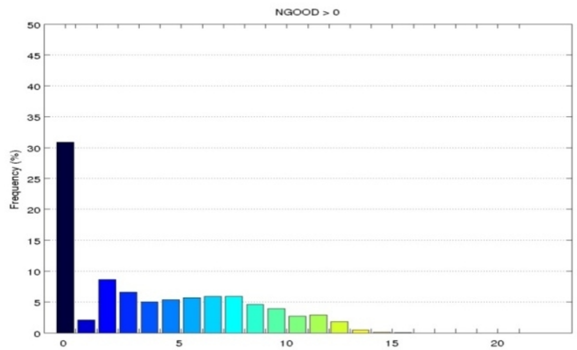




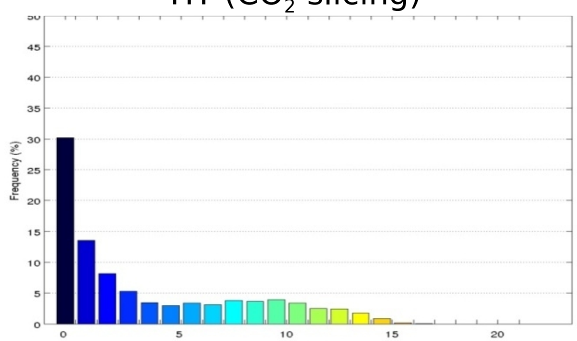
Neglecting the weak detection of multilayer cloud, the bias model vs retrieved cloud height is quite stable

Validation results: cloud top height distribution

July 1st, 2008 , 0 Z

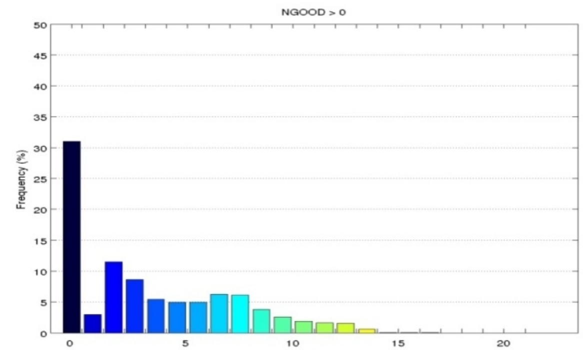


HT (CO_2-slicing)

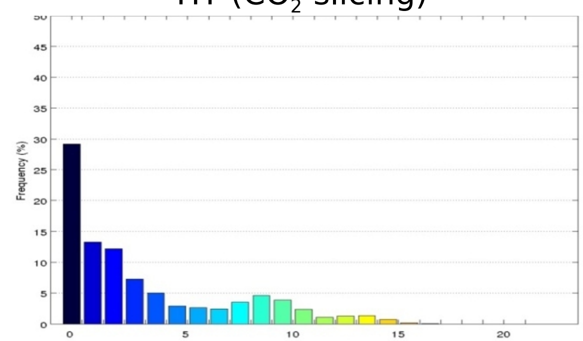


HT (direct model)

July 31th, 2008 , 0 Z



HT (CO_2-slicing)

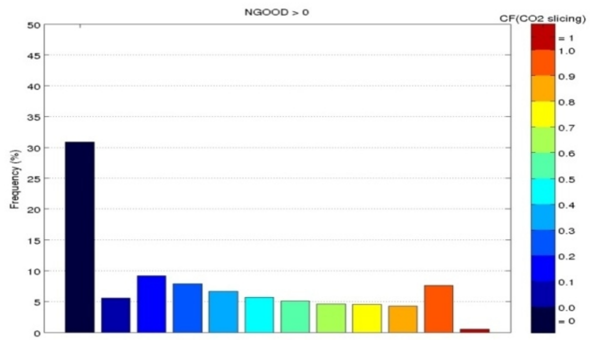


HT (direct model)

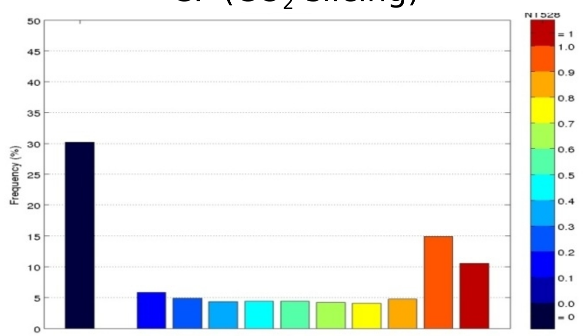
Relatively good agreement for mid and high level clouds
The model detects more low level clouds

Validation results: cloud fraction distribution

July 1st, 2008 , 0 Z

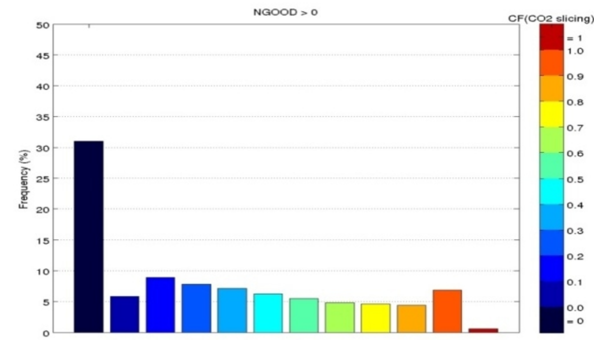


CF (CO_2-slicing)

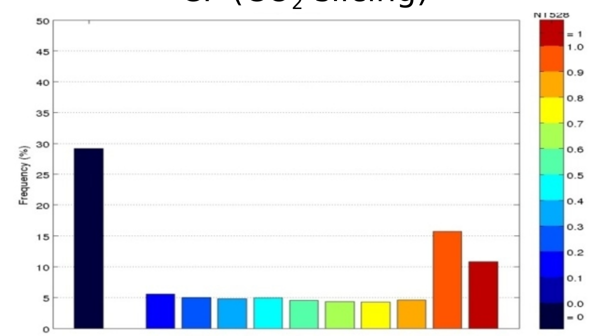


CF (direct model)

July 31th, 2008 , 0 Z



CF (CO_2-slicing)



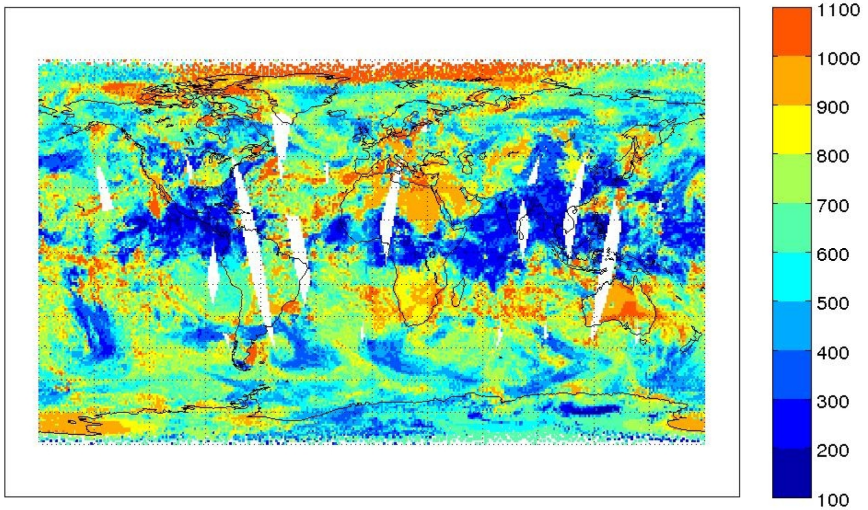
CF (direct model)

Good overall agreement except high cloud amounts (> 0.9)
Model second bin = 0 as threshold consequence

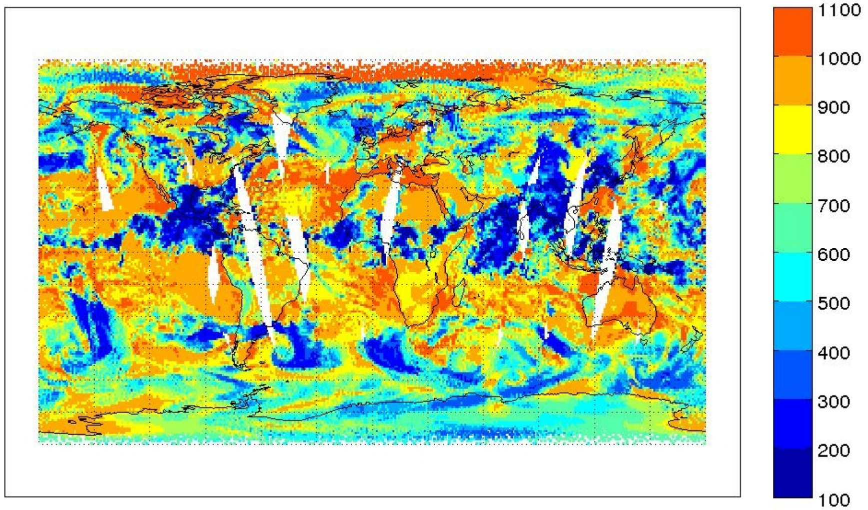
Validation results: daily maps of cloud parameters

Cloud Top Pressure (July 1st 2008)

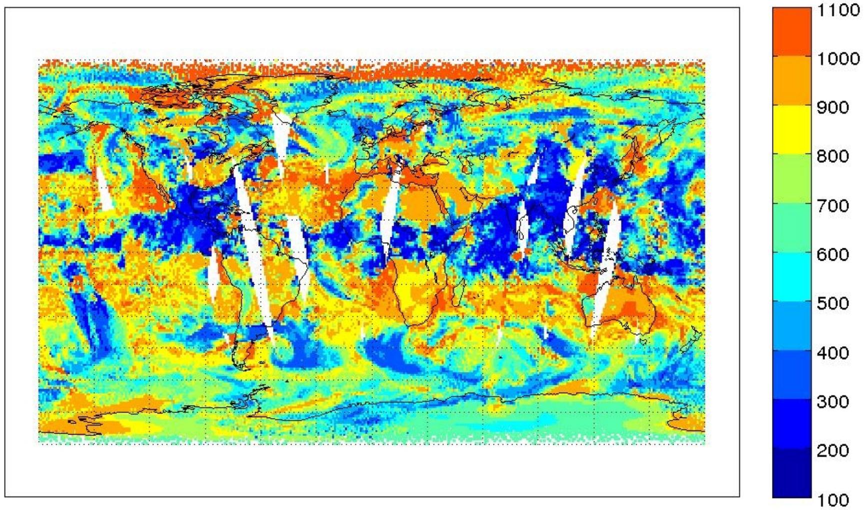
Observed CTP



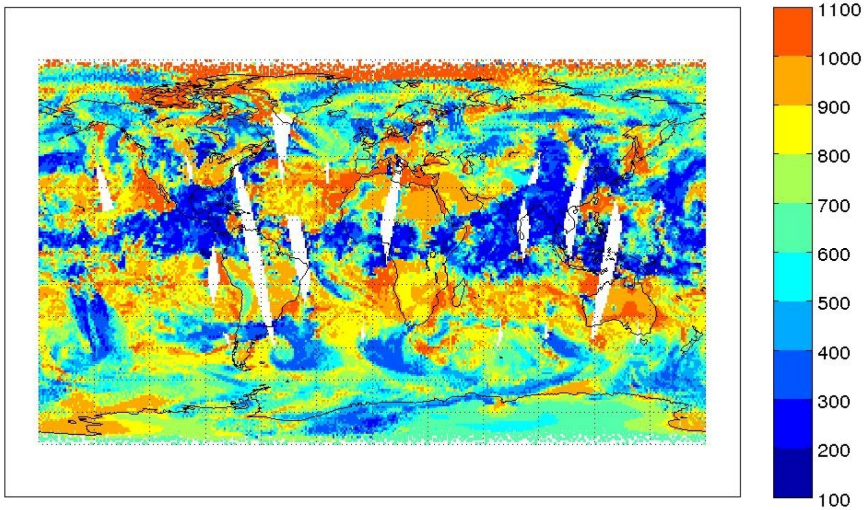
Direct model output CTP



Calculated CTP – 3-9h forecast



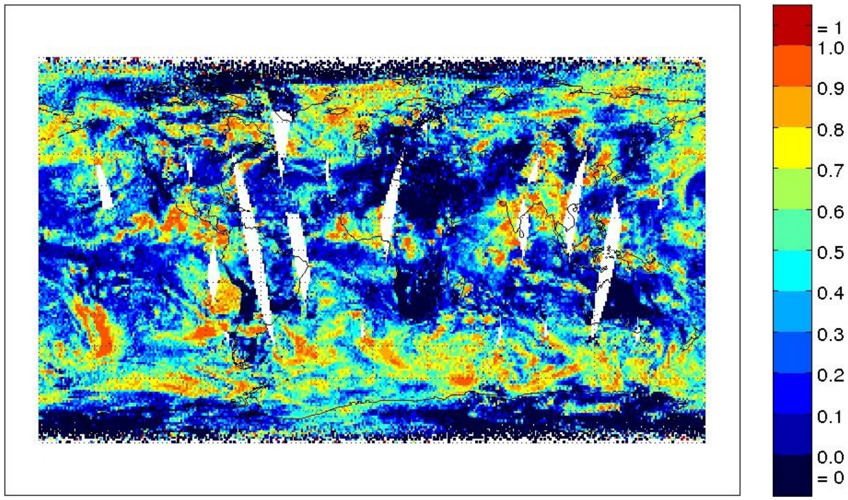
Calculated CTP – 9-15h forecast



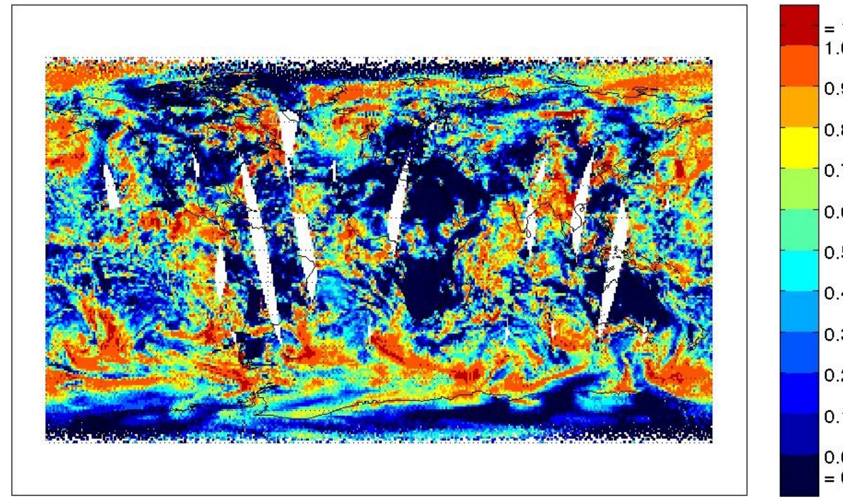
Validation results:
daily maps of cloud parameters

Cloud Fraction (July 1st 2008)

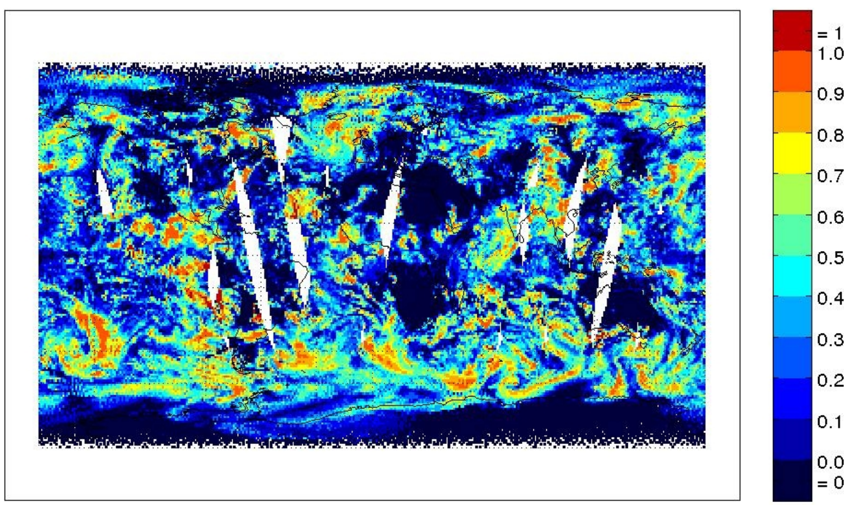
Observed CF



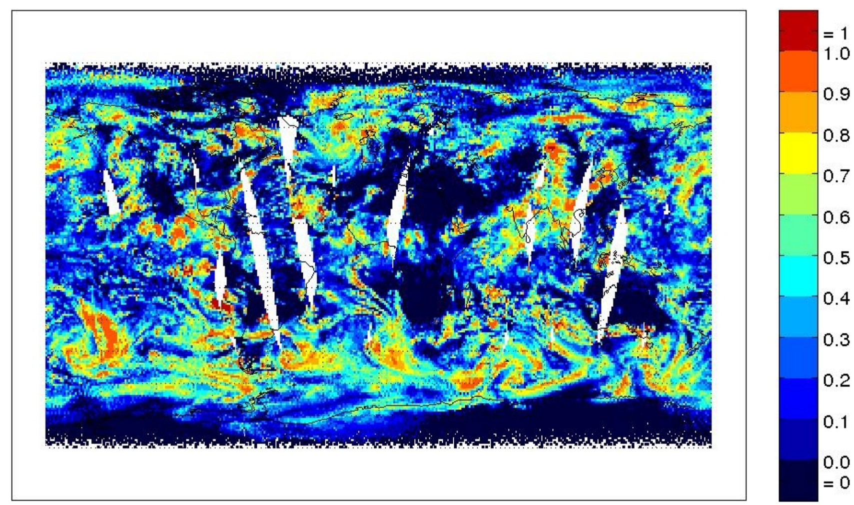
Direct model output CF



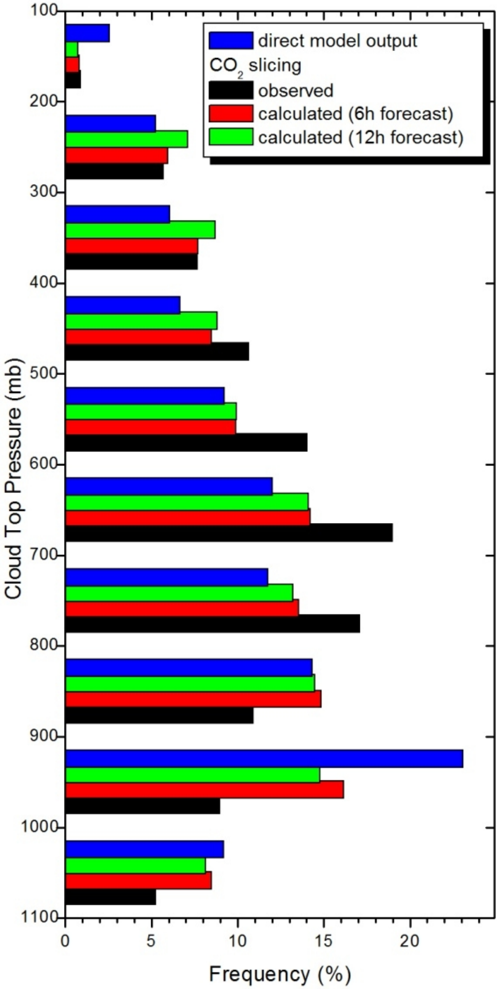
Calculated CF – 3-9h forecast

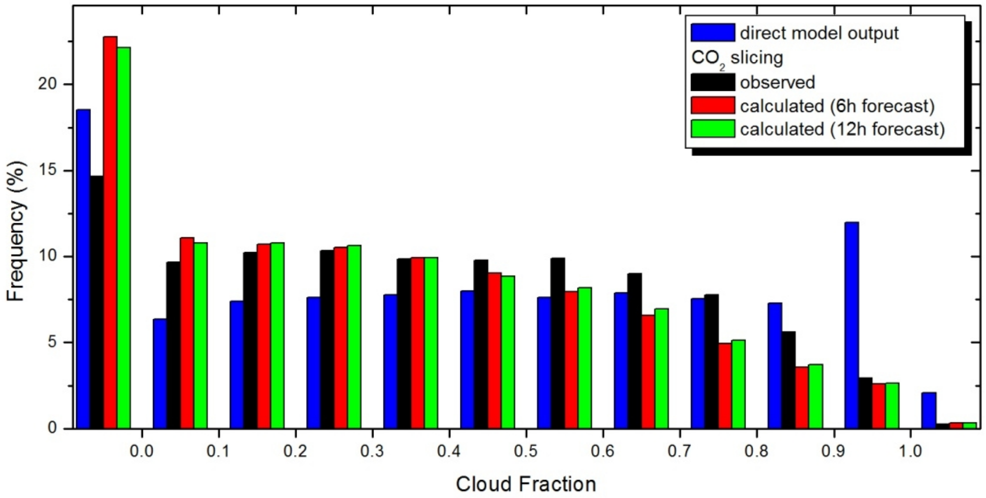


Calculated CF – 9-15h forecast



Validation results:
daily global distributions of cloud parameters





The quality of 3 – 9 h forecasts is about the same at 9 – 15 h.

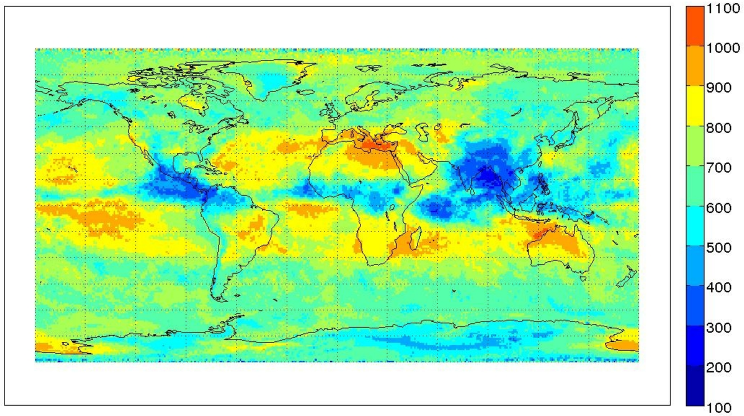
Slight deficit in model mid level clouds

Retrieval method sees clouds above 300 hPa lower

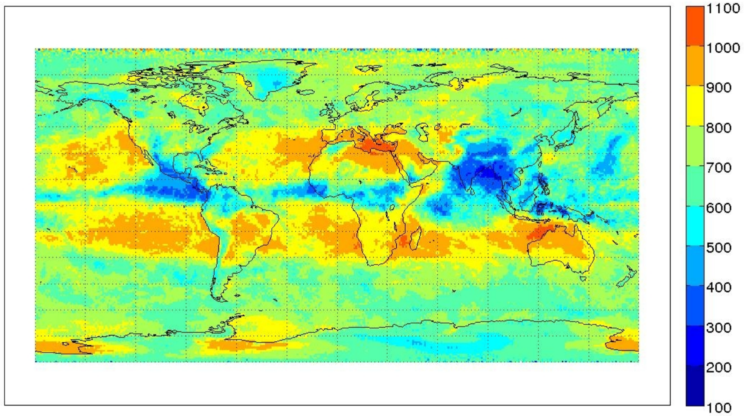
Validation results:
monthly maps of cloud parameters

Cloud Top Pressure (July 2008)

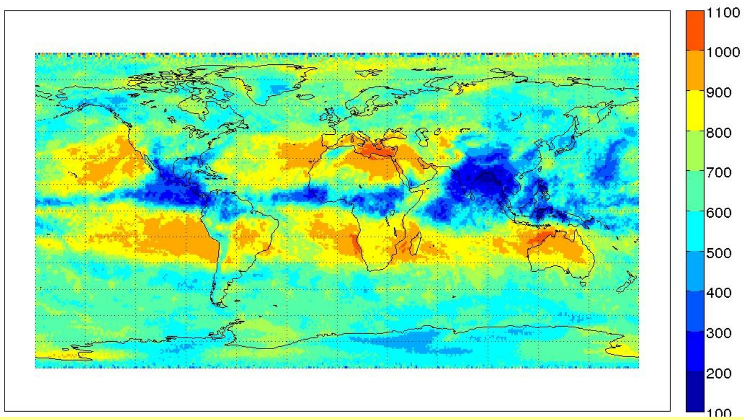
Observed CTP



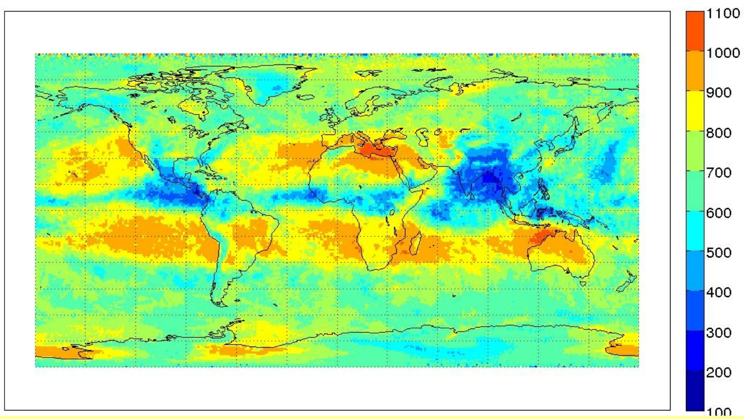
Direct model output CTP



Calculated CTP – 3-9h forecast



Calculated CTP – 9-15h forecast

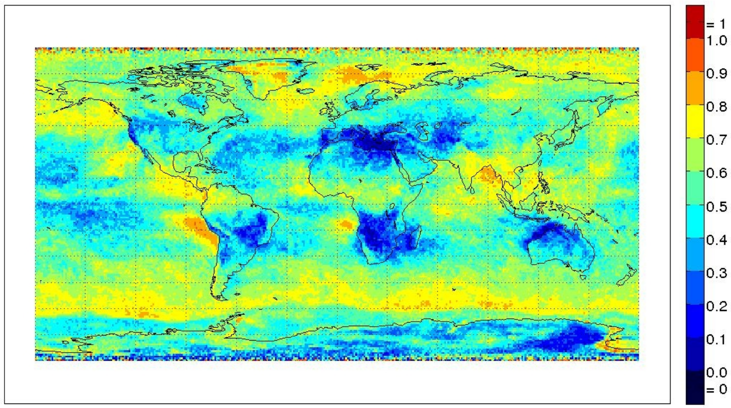


Good overall agreement between observed, calculated and direct model output CTP.
Differences most notable for low clouds on west of continents.

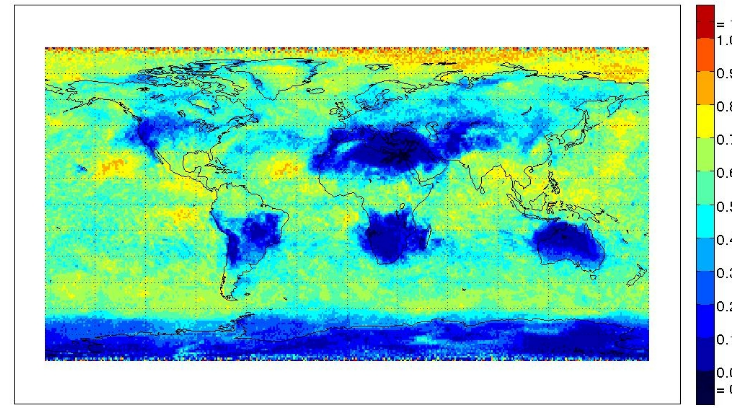
Validation results:
monthly maps of cloud parameters

Cloud Fraction (July 2008)

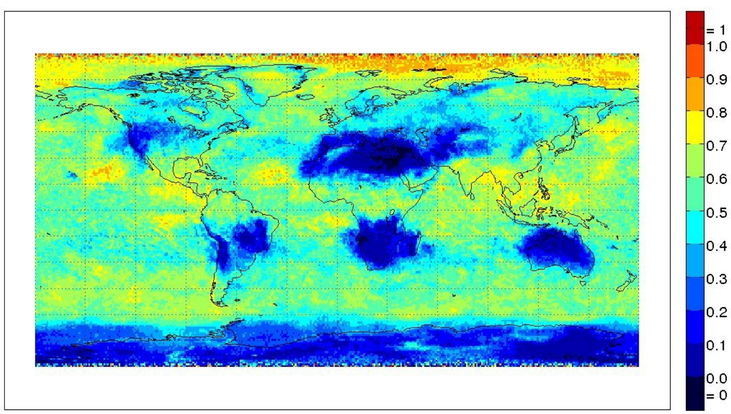
Observed CF



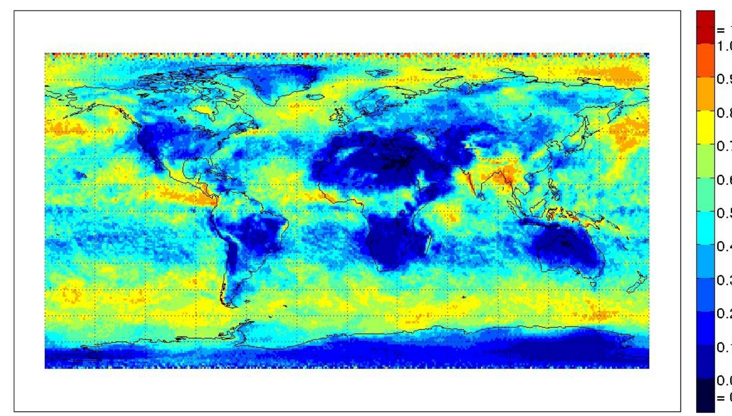
Direct model output CF



Calculated CF – 3-9h forecast



Calculated CF – 9-15h forecast



Weak values of cloud fraction over Antarctica

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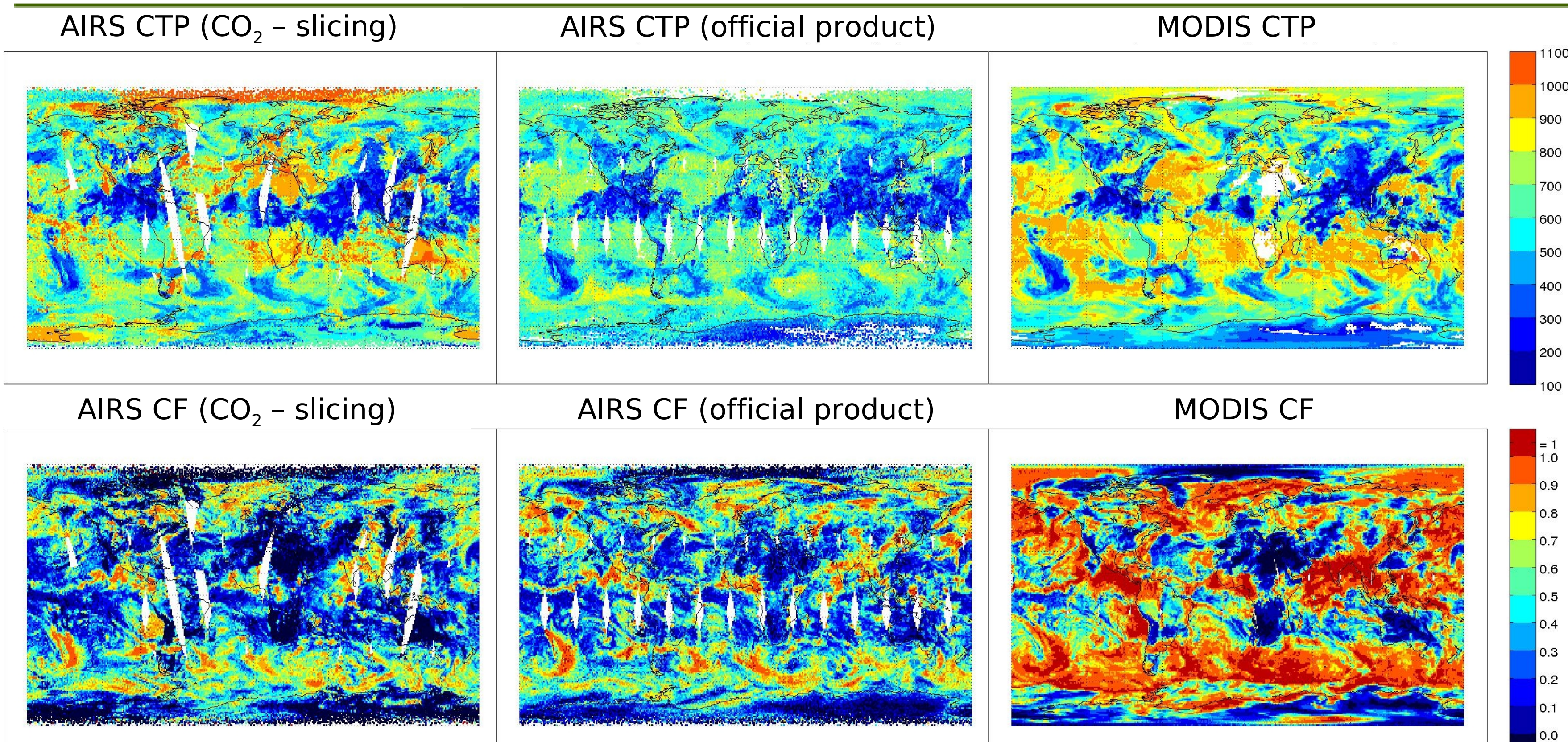
Cloud parameters comparison with independent data sources: daily maps (July 1st 2008)



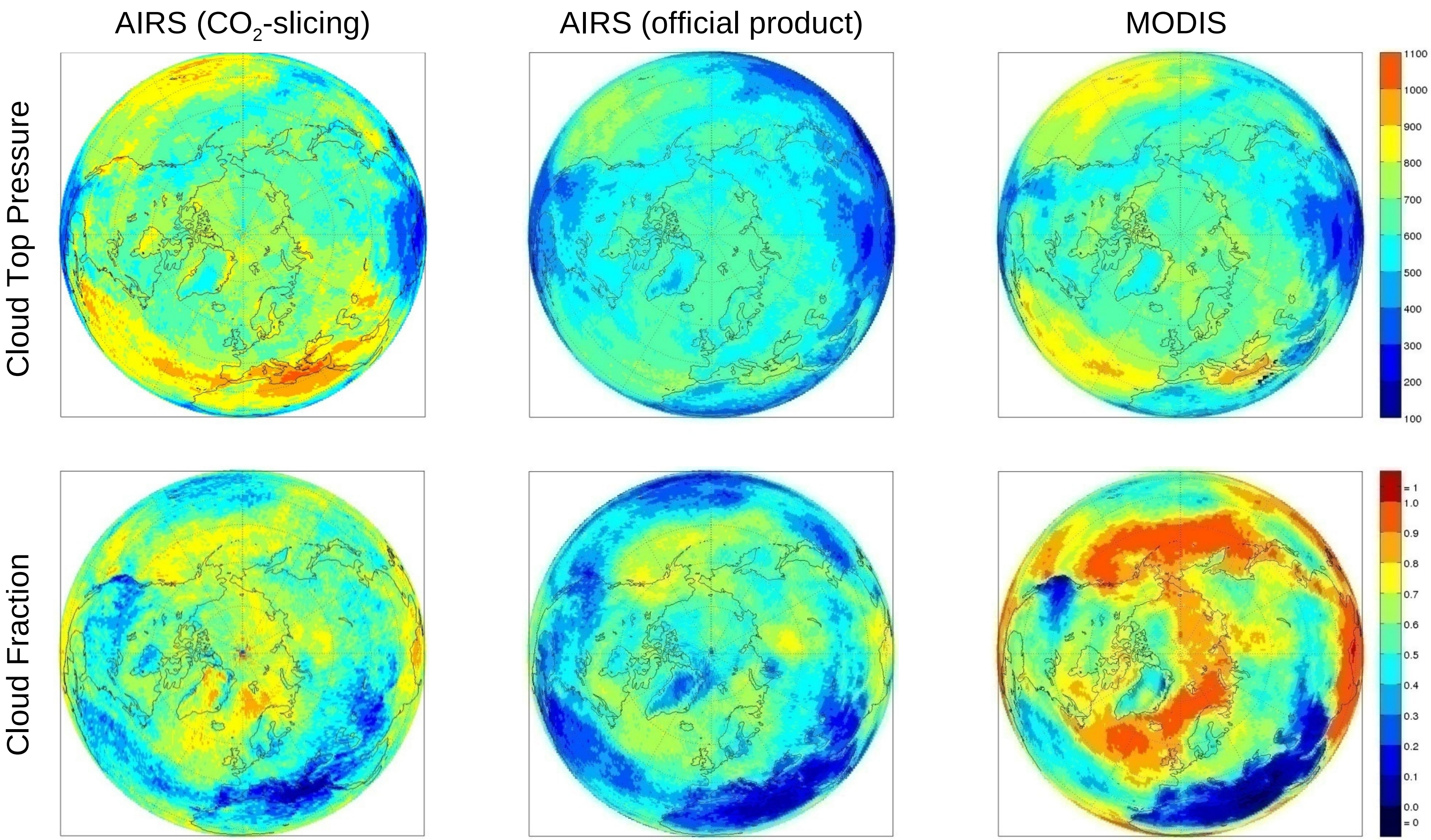
Source: AIRS science team

Source: MODIS science team

AIRS-JPL tops significantly higher than EC or MODIS tops due to different retrieval techniques.
MODIS patterns very similar to EC but cloud fraction often higher, reaching 100 % over broad areas.
Largest differences in Southern Hemisphere, linked to polar night

Focus on Arctic areas (July 2008):

Cloud parameters comparison with independent data sources

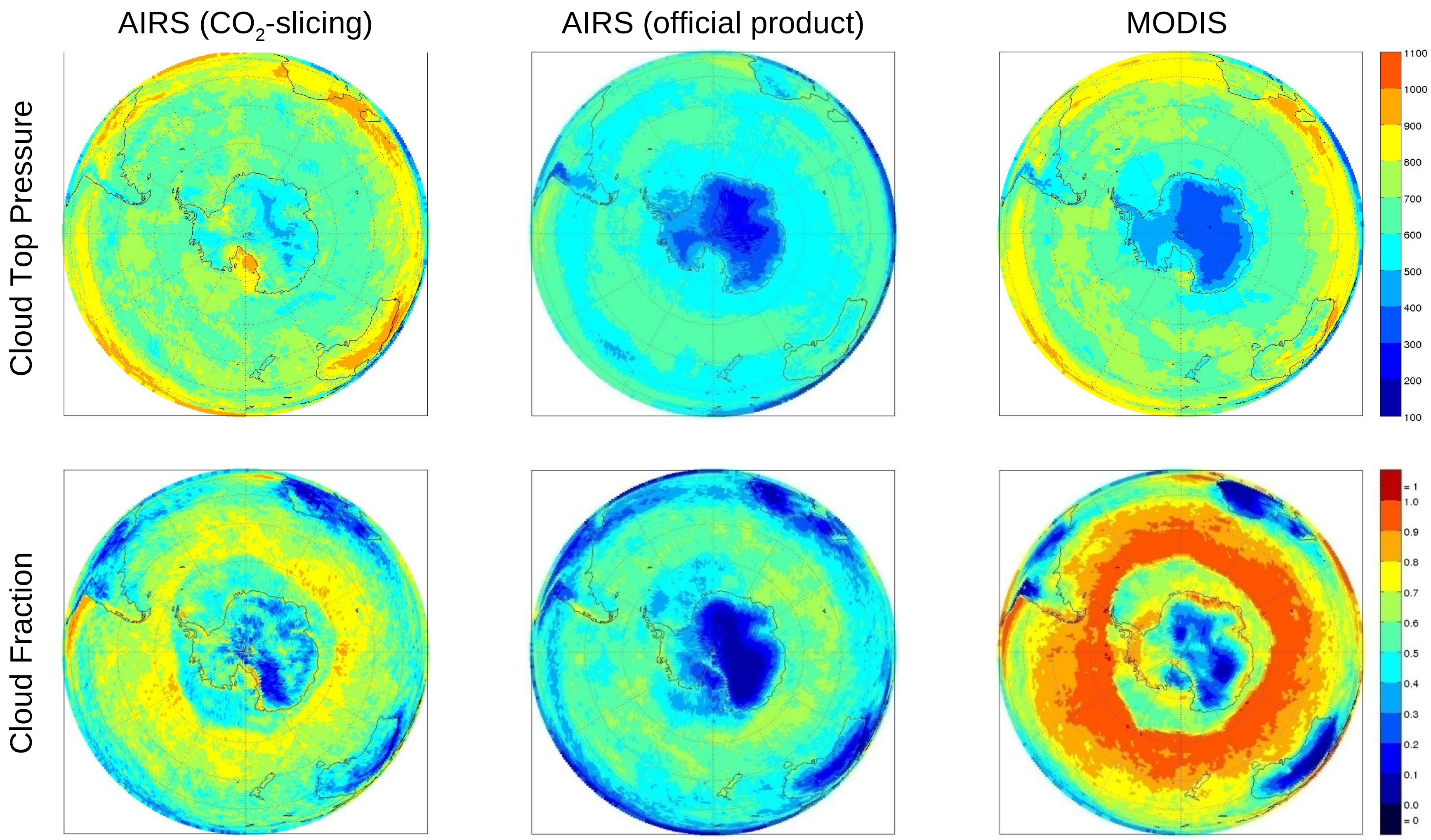


Source: AIRS science team

Source: MODIS science team

Focus on Antarctic areas (July 2008):

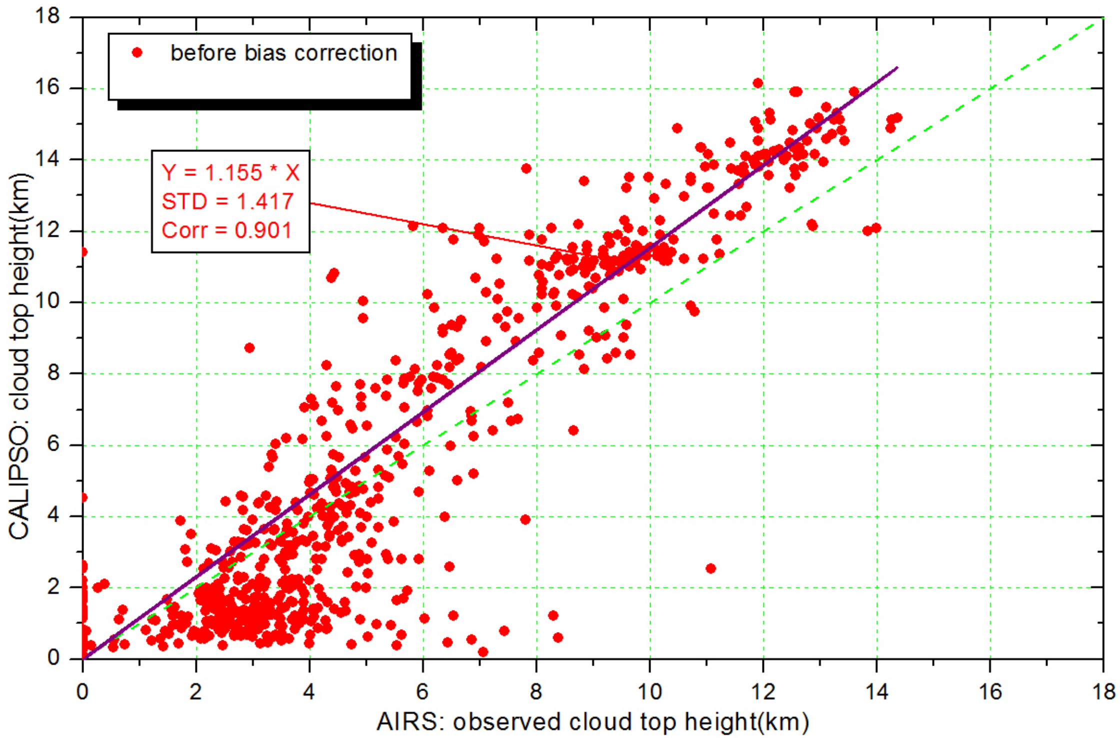
Cloud parameters comparison with independent data sources



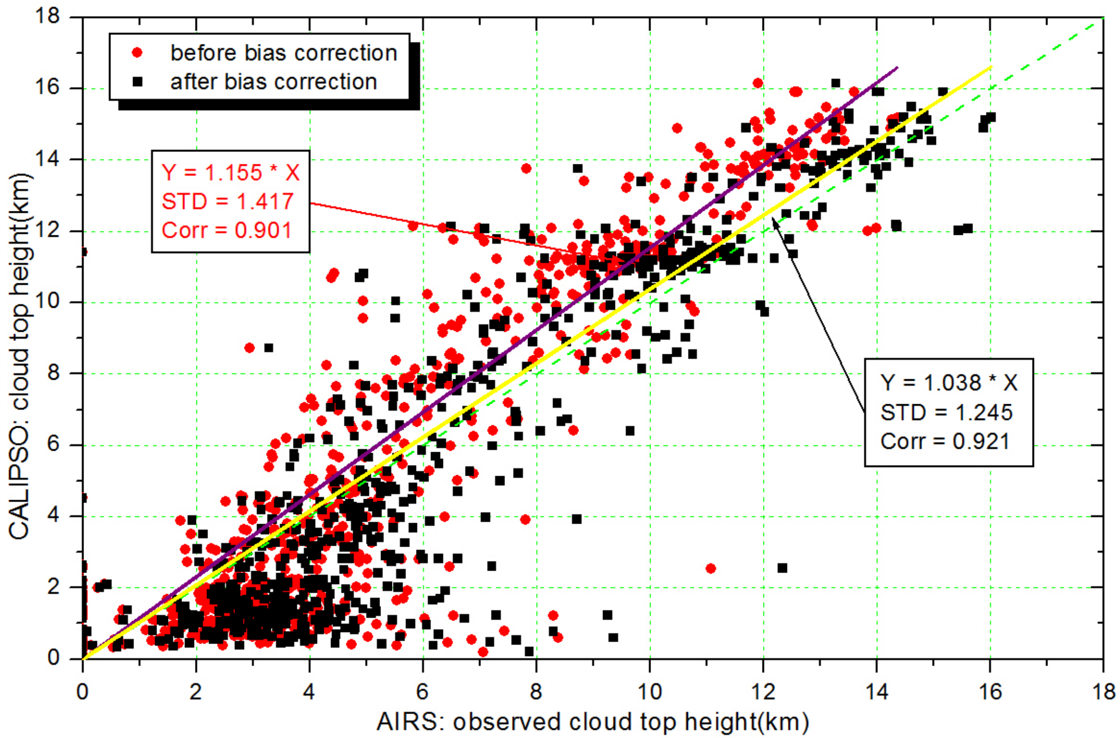
Source: AIRS science team

Source: MODIS science team

Comparison CALIPSO vs AIRS cloud top heights (July 1st 2008, 00Z)



Comparison CALIPSO vs AIRS cloud top heights (July 1st 2008, 00Z)



CALIPSO: 5km cloud product – only single layer clouds
Bias correction: observed AIRS heights were corrected according to the bias obtained by model validation

Good correlation between retrieved AIRS and CALIPSO heights, improved after bias correction

Conclusion and Perspectives

- Using model output combined with calculated cloudy radiances allows to validate cloud parameter retrieval methodology for climate studies (notably minimize systematic retrieval biases on height)
- Observed and retrieved parameters at EC remarkably similar. Cloud tops from model output slightly higher. However results sensitive to threshold τ_{cloud}
- Work in progress: continuing improving the CO_2 – slicing algorithm taking into account the emissivity differences between chosen channels
- Develop validation statistics for cloudy radiance spectra
- Validation of AIRS-derived cloud parameters with independent data, in particular for polar winter cases
- Assimilation tests with revised quality control
- Collaboration to IPY research on ice cloud parameterization
- Extend application to IASI, using available sub-grid information from AVHRR allowing to distinguish single layer clouds (where CO2 - slicing works best) from multilayered clouds (where cloud tops are seen too low)
- Publication on improved methodology suitable for both real time and climate applications. Other publication specific to polar applications.